Performance of a Group of Mathematically Able Youths on the Mathematics Usage and Natural Sciences Readings Tests of the American College Test Battery vs. the Scholastic Aptitude Test

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In February of 1977 the Study of Mathematically Precocious Youth (SMPY) at The Johns Hopkins University used for the first time in its talent searches two tests from the American College Test (ACT) battery: the Mathematics Usage (ACT-M) and Natural Sciences Readings (ACT-NS) tests. In addition, three tests from the Differential Aptitude Test (DAT) battery and an Algebra I achievement test were administered to the top-scoring 278 contestants from the 1976-77 Mathematics Talent Search conducted by SMPY.

Identifying the Talent Pool

The 278 youths comprising the top-scoring third were selected for further testing from a group of 873 Talent Search participants from Maryland and surrounding areas. Eligibility requirements for initial screening of the Talent Search participants included being in seventh grade (or of seventh-grade age but in higher grades) and having scored at or above the 97th percentile of national public school norms on in-grade mathematics tests. Equivalently, the students could have scored at or above the 95th percentile of the more rigorous private school norms or the 98th percentile of the weaker urban norms.[1]

The 873 students were given the mathematical and verbal sections of the College Entrance Examination Board Scholastic Aptitude Test (SAT-M and SAT-V) in December of 1976. Then 278 students (188 males and 90 females) were selected for further testing by meeting the following criterion: $2(\text{SAT-M}) + 1(\text{SAT-V}) \geq 1330$. This top-scoring group was selected mainly for mathematical aptitude, inasmuch as their scores on the mathematical section of the SAT carried twice the weight of those on the

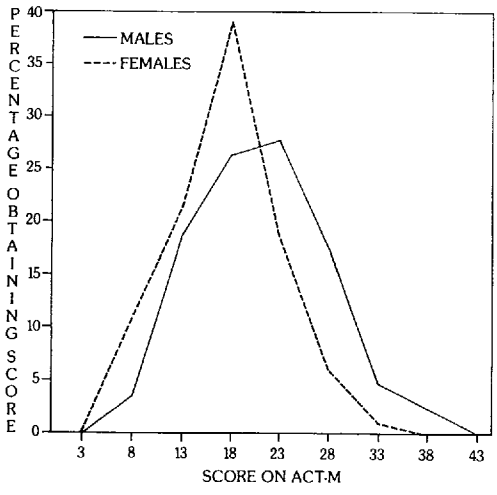

Figure 1: Distributions of the ACT-M scores of the 188 males and 90 females in the 1976 retest group. Percentages are plotted against the midpoints of score ranges.

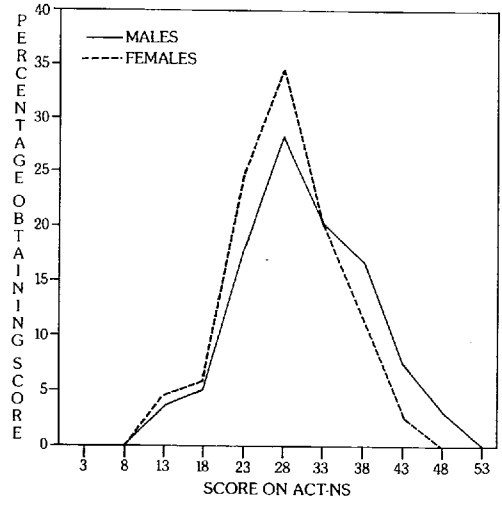

Figure 2: Distributions of the ACT-NS scores of the 188 males and 90 females in the 1976 retest group. Percentages are plotted against the midpoints of score ranges.

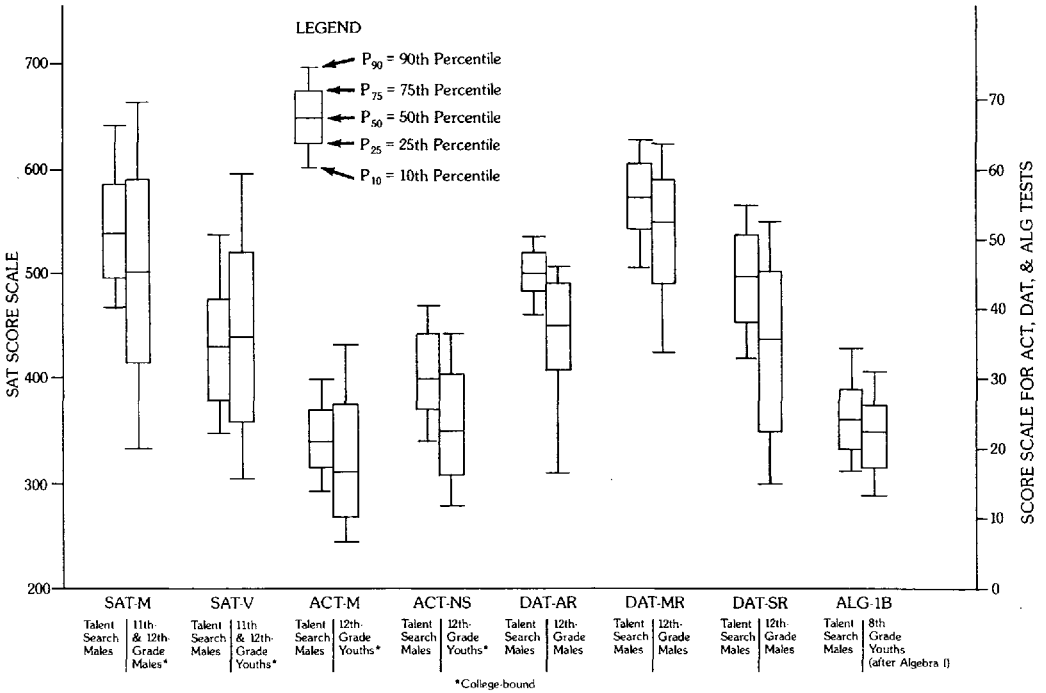

Figure 3. Comparison of scores earned on 8 cognitive tests by 7th-grade males (N=188) from the December 1976 Talent Search who were called back for further testing with the scores earned by various normative groups of older youths. NOTE: Since the score scales are not equivalent across the different tests, compare the scores earned by the Talent Search males on a particular test with the scores earned by the normative group for that test only.

verbal section. The use of this criterion guaranteed that students having only moderately high mathematics-aptitude scores but very high verbal scores would be included in the retest group, and that none with fairly high SAT-M scores would be excluded.

Second Testing Session

In February of 1977 these top-scoring students received 6½ hours of further testing of their abilities, interests, and values. The two ACT tests were the first ability measures administered in the morning of the retest session. Other tests given included a form of the Cooperative Mathematics test of Algebra I (Alg. I), three reasoning subtests of the Differential Aptitude Test (DAT) battery (Abstract Reasoning, Mechanical Reasoning, and Space Relations), and two noncognitive inventories. This discussion will focus primarily on the relationships between scores on the ACT and SAT tests, since both tests are used to assess ability of students entering college.

Distribution of Scores on the ACT Subtests

The scores on the ACT-M, a 40-item test, ranged from 7 to 31 for the females and from 7 to 40 for the males. On the 52-item ACT-NS, scores ranged from 14 to 43 for the females and from 12 to 48 for the males. Figures 1 and 2 give the frequency polygons for the distributions of the scores of both males and females on the ACT-M and the ACT-NS, respectively. From these graphs it is evident that the distributions of scores on both tests are not very skewed for either sex. Only the distribution of ACT-M scores for the males has a significantly different skewness from that of the normal distribution.[2] Also, very few students made the highest scores possible on these tests. On both tests the lowest scores were in the range expected by chance, assuming that all items were marked by the examinees. A pure chance score on the ACT-M is 8; on the ACT-NS it is 13. Both sections of the ACT appear to have adequate floor and ceiling for most members of this talented group of students.

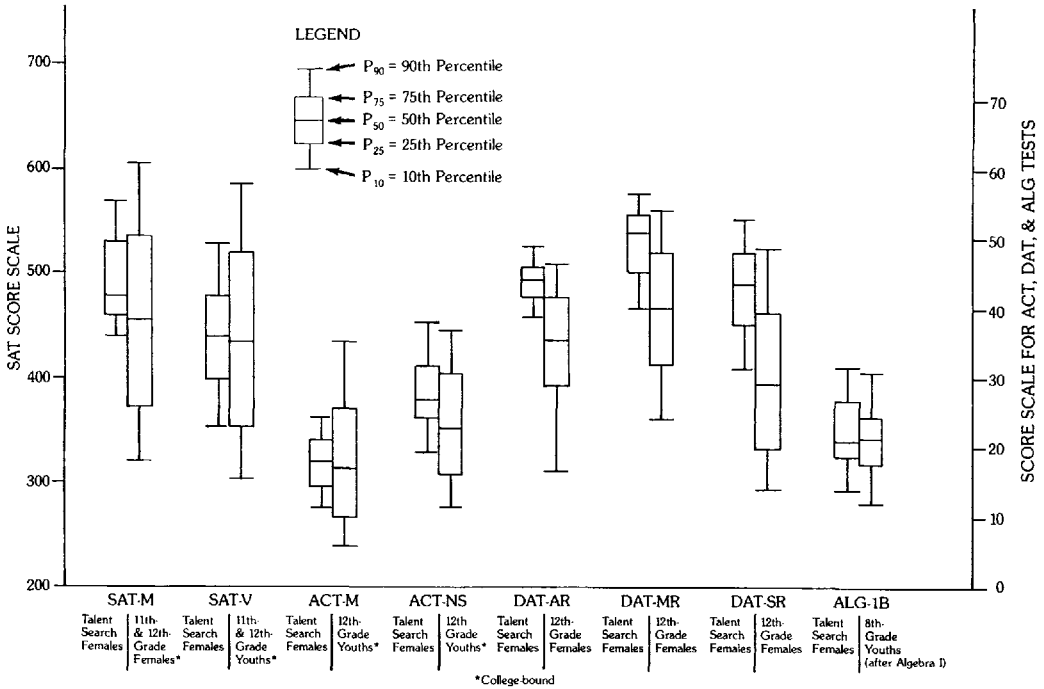

Figure 4. Comparison of scores earned on 8 cognitive tests by 7th-grade females (N=90) from the December 1976 Talent Search who were called back for further testing with the scores earned by various normative groups of older youths. NOTE: Since the score scales are not equivalent across the different tests, compare the scores earned by the Talent Search females on a particular test with the scores earned by the normative group for that test only.

Comparisons of Score Distributions of Males and Females in the Retest Group with Those of Normative Groups of Older Youths

In Figure 3 the scores of the 188 males in the retest group are compared with those of several normative groups composed of older students (Cohn, 1977). The most stringent same-sex norms available were used for comparison with the retest group. If same-sex norms were not available, norms for the most stringent composite group were used. The median scores for the Talent Search males were above the medians for the normative groups of college-bound 11th- and 12th-graders on every test except SAT-V. On both ACT-M and ACT-NS less than 10% of the Talent Search males scored below the median of college-bound 12th-graders.

Figure 4 depicts analogous comparisons for the scores of the 90 retest group females. The median scores for the retest females were above the medians for the normative groups on all tests except the Alg. I, where there was a slight difference in favor of eighth-graders who had already completed a school year of instruction in algebra.

Comparison of ACT with SAT

Although the ACT was administered two months after the SAT, there are many significant intertest correlations for both males and females. (See Tables 1 and 2 for males and females, respectively.)

ACT-M and SAT-M

The correlations between ACT-M and SAT-M are .74 for the males and .56 for the females ($p \leq .001$ in both cases). This suggests that for both sexes in the highly select retest group, restricted in range on both SAT-V and SAT-M, ACT-M and SAT-M measure rather similar abilities. ACT-M, which includes numerous specific knowledge questions, seems to be more dependent on the subject matter taught in mathematics courses than is SAT-M.

ACT-M and SAT-V

The correlations of ACT-M with SAT-V for both sexes resemble the correlations of SAT-M with SAT-V. For the males, SAT-V correlates significantly with both ACT-M and SAT-M (.26 and .21, respectively), but for the females they are essentially independent (.06 and −.10). It is interesting to note that the correlations of both ACT-M and SAT-M with SAT-V are nonsignificant for those males whose scores fell within the score ranges for the females on ACT-M and SAT-M.[3] This suggests that the abilities measured by ACT-M and the explicitly restricted SAT-V are essentially independent for both sexes in this highly able sample. The higher correlation for the males is largely due to a few males who scored exceptionally well on both measures. Perhaps these males have a higher level of general intelligence which contributed to their excellent scores on these three tests.

ACT-NS and SAT-V

The correlation of ACT-NS with SAT-V is highly significant for both sexes in the retest group; .63 for boys and .52 for girls ($p \leq .001$ in both cases). This suggests that there is a rather strong verbal component in the Natural Sciences Readings test, an assertion corroborated by its format. A comparison of this correlation with the correlations between ACT-NS and the mathematics measures shows that ACT-NS correlates most highly with SAT-V.[4] For the males the correlation of ACT-NS with SAT-V is significantly higher than the correlations of ACT-NS with ACT-M, SAT-M, and Alg. I ($p \leq .001$ in all cases). For the females the ACT-NS/SAT-V correlation is significantly different from all correlations except that of ACT-NS with ACT-M.[5]

ACT-NS and SAT-M

Though the ACT-NS correlates more highly with the SAT-V than with any of the other measures given, it does correlate positively with these other measures. The correlation of ACT-NS with SAT-M is .26 for the males ($p \leq .001$) and .14 for the females. Again, however, the correlation of ACT-NS with SAT-M for the 160 males scoring in the females' range on SAT-M is a nonsignificant .05. The scores of a few highly able males have contributed heavily to the high correlations for the full groups of males. The mainly verbal ACT-NS seems to measure an ability that, for this group, is largely independent of the mathematical reasoning ability measured by the SAT-M.

Intercorrelations of the ACT Subtests

The ACT-NS, however, correlates with ACT-M, with values of .31 for the males and .35 for the females ($p \leq .001$ in both cases). That the two ACT subtests intercorrelate more highly than do the ACT-NS and SAT-M could be expected, since the ACT-M and ACT-NS were given on the same day and are from the same test battery. These correlations also suggest that the ACT-NS may have a mathematical or perhaps a computational component; indeed, some of the items on the ACT-NS involve the use of mathematical formulas and computations.

The ACT Subtests and the Test of Algebra I

ACT-M and Alg. I

As one would expect, the correlation of ACT-M with Alg. I is highly significant for both sexes. ACT-M contains many items with algebraic content, so Alg. I, a test of algebra knowledge, could be expected to be rather similar. The correlations of .68 for the males and .67 for the females support this prediction.

ACT-NS and Alg. I

These two tests are significantly intercorrelated for both males and females in the retest group, with correlation coefficients of .18 and .28, respectively. This result is not unexpected, since the ACT-NS also correlates positively with the other math measures. This may reflect the fact that there is a small computational, possibly algebraic, component to the ACT-NS. Though statistically significant, these correlations are not very large; the amount of variance common to the two tests is only 3% for the males and 7% for the females.

Table 1

Coefficients of Correlation among 5 Cognitive Measures for the 188 Males in the 1976 Talent Search Retest Group*

	ACT-M	SAT-M	ACT-NS	SAT-V	Alg. I
ACT-M	—	.74+	.31+	.26+	.68+
SAT-M	—	—	.26+	.21°	.63+
ACT-NS	—	—	—	.63+	.18°
SAT-V	—	—	—	—	.17°

°$p \leq .01$ +$p \leq .001$

*For significance testing, correlation coefficients were calculated to four decimal places.

Table 2

Coefficients of Correlation Among 5 Cognitive Measures for the 90 Females in the 1976 Talent Search Retest Group*

	ACT-M	SAT-M	ACT-NS	SAT-V	Alg. I
ACT-M	—	.56+	.35+	.06	.67+
SAT-M	—	—	.14	−.10	.50+
ACT-NS	—	—	—	.52+	.28°
SAT-V	—	—	—	—	.02

°$p \leq .01$ +$p \leq .001$

*For significance testing, correlation coefficients were calculated to four decimal places.

Table 3
Rotated Factor Matrices for the Factor Analysis of the Scores of the 188 Retest Group Males on the 8 Cognitive Measures

	Mathematics Factor	Nonverbal Reasoning Factor	Verbal Reasoning Factor	Communalities (h^2)
ACT-M	.88	.16	.17	.83
SAT-M	.79	.21	.11	.68
Alg. I	.76	.00	.09	.59
DAT-AR	.30	.55	.00	.39
ACT-NS	.14	.31	.81	.77
SAT-V	.14	.04	.73	.55
DAT-SR	.12	.90	.12	.84
DAT-MR	-.03	.64	.24	.47
Eigenvalues	2.12	1.69	1.31	
Percent of common variance explained	41	33	26	
Percent of total variance explained	27	21	16	64*

The matrix entries represent the correlations of the 8 measures with each of the 3 factors.
*64% of the total variance of the 8 measures is common variance.

Table 4
Rotated Factor Matrices for the Factor Analysis of the Scores of the 90 Retest Group Females on the 8 Cognitive Measures

	Mathematics Factor	Verbal Reasoning Factor	Nonverbal Reasoning Factor	Communalities (h^2)
ACT-M	.87	.14	.06	.78
SAT-M	.61	-.04	.43	.56
Alg. I	.73	.09	.16	.57
DAT-AR	.40	.09	.22	.22
ACT-NS	.27	.78	.04	.68
SAT-V	-.03	.68	-.14	.48
DAT-SR	.36	.01	.43	.31
DAT-MR	.10	-.11	.56	.34
Eigenvalues	2.04	1.12	0.78	
Percent of common variance explained	52	28	20	
Percent of total variance explained	26	14	10	50*

The matrix entries represent the correlations of the 8 measures with each of the 3 factors.
*50% of the total variance of the 8 measures is common variance.

A Factor Analysis of the Cognitive Measures

Factor analysis is a technique of multivariate analysis that groups the tests or variables analyzed according to the variance in common between them. Factor analyses were performed separately for the two sexes on their scores on eight tests: the two ACT subtests, SAT-M and SAT-V, Alg. I, and the three tests from the Differential Aptitude Test battery (Abstract Reasoning, Mechanical Reasoning, and Space Relations). The principal factoring method was used to extract the initial factors; this method is based on the theory of common factors which suggests that the variance of each test is composed of the error variance, a unique component, and a component common to other tests (also called the communality).[6]

The factor analyses produced three identifiable factors for both sexes.[7] Tables 3 and 4 show the rotated factor matrices for the males and females, respectively. The first factor for both sexes was obviously a mathematics factor. For the males this factor accounted for 41% of the variance common to the eight measures. The males' second factor appeared to be a nonverbal reasoning factor, primarily concerned with spatial reasoning ability. The largest loading on this factor, .90, was for the DAT test of Space Relations. The other DAT tests have weights of at least .55, but the next largest loading was for the ACT-NS, only .31. The final factor for the males was a verbal reasoning factor. The largest weight on this factor was for ACT-NS, followed rather closely by that for SAT-V. All other weights were less than .25.

As previously mentioned, the first factor for the females was a mathematics factor. It accounted for 52% of the variance common to the eight tests. The ACT-M had the highest loading on this factor for the females, as it had for the males. The DAT-AR, however, had a loading of .40 on the mathematics factor for the females, but only a loading of .30 for the males.

The second factor for the females was identical to the males' third verbal reasoning factor. Again, the ACT-NS and SAT-V had the only sizable loadings, .78 and .68, respectively. The final factor for the females was a reasoning factor, but was not very similar to the males' nonverbal reasoning factor. The loadings on this factor were all less than .60, and only three tests, the DAT-MR, DAT-SR, and SAT-M, had loadings above .22. Because of such relationships and the low eigenvalue (0.78), one should probably not pay much attention to this factor.

Conclusion

A number of points seem apparent from the above discussions. The first is that the Mathematics Usage and

Natural Sciences Readings Tests of the ACT battery have adequate ceiling and floor for this group of mathematically talented students who are four or five years younger than the usual ACT examinees. The Mathematics Usage test of the ACT correlates well with both the SAT-M and a test of Algebra I achievement. A factor analysis grouped these three tests on a mathematics factor for both boys and girls in the SMPY Talent Search group. The Natural Sciences Readings test correlates highly with the SAT-V, and is grouped with the SAT-V in a verbal reasoning factor for both sexes. The ACT-NS also correlates with the mathematics measures, suggesting that it may have a computational or mathematical reasoning component as well as its mainly verbal component.

SMPY will continue to use SAT-M as the initial screening instrument for mathematics talent searches among seventh-graders in the Middle Atlantic Region who are already known to score in the top 3% on national norms for the mathematics section of an achievement-test battery, such as the Iowa Test of Basic Skills. This will be done chiefly because the subject matter demands of SAT-M are less than those of ACT-M. ACT-M can be quite useful, however, for further study of the high scorers on SAT-M (e.g., those earning at or above 500, slightly above the average for college-bound male 12th-graders). ACT-NS is a good basic screening test of science "aptitude" for this able group. It may be followed by a more subject-matter-oriented test such as Level 1 of Educational Testing Service's Sequential Tests of Educational Progress (STEP) in science.

Further comparative study of SAT and ACT tests is planned.

Footnotes

1. For detailed background see Stanley (1977) and Stanley, Keating, and Fox (1974).
2. This distribution had a skewness of .482, significantly different from zero at the .05 level.
3. The correlation of SAT-V with ACT-M is .14 for the 176 males who scored 31 or less on ACT-M. The correlation of SAT-V with SAT-M is -.06 for the 160 males who scored 610 or less on SAT-M.
4. Comparisons were tested using the *Z*-statistic for difference between correlated correlation coefficients. (Hendrickson & Collins, 1970, p. 639.)
5. For females, significance levels were $p < .01$ for the comparison of the ACT-NS/SAT-V correlation (.52) with the ACT-NS/SAT-M correlation (.14); $p < .05$ for the comparison of the ACT-NS/SAT-V with the ACT-NS/Alg. I correlation (.28); and $p < .10$ for the comparison of the ACT-NS/SAT-V correlation with the ACT-NS/ACT-M correlation (.35).
6. The method of factor analysis used to extract the initial factors was that provided in an option of the SPSS factor analysis subroutine. This is an iterative method that uses the correlation matrix modified by the replacement of the diagonal elements with communality estimates. The initial factors were then rotated, using the varimax procedure.
7. The number of factors was set at three for both sexes. Only two factors were extracted for the girls when the program was allowed to extract only those factors having eigenvalues greater than one.

References

Cohn, S. J. Cognitive characteristics of the top-scoring third of the 1976 Talent Search contestants. *ITYB* (Intellectually Talented Youth Bulletin), 1977, *3* (10), 3-6.

Hendrickson, G. F., & Collins, J. R. Note correcting the results in "Olkin's new formula for the significance of r_{13} vs. r_{23} compared with Hotelling's method." *American Educational Research Journal*, 1970, *7*, 639-641.

Stanley, J. C. Rationale of the Study of Mathematically Precocious Youth (SMPY) during its first five years of promoting educational acceleration. In J. C. Stanley, W. C. George, & C. H. Solano (Eds.), *The gifted and the creative: A fifty-year perspective*. Baltimore, MD: The Johns Hopkins University Press, 1977, 75-112.

Stanley, J. C., Keating, D. P., & Fox, L. H. (Eds.). *Mathematical talent: Discovery, description, and development*. Baltimore, MD: The Johns Hopkins University Press, 1974.

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